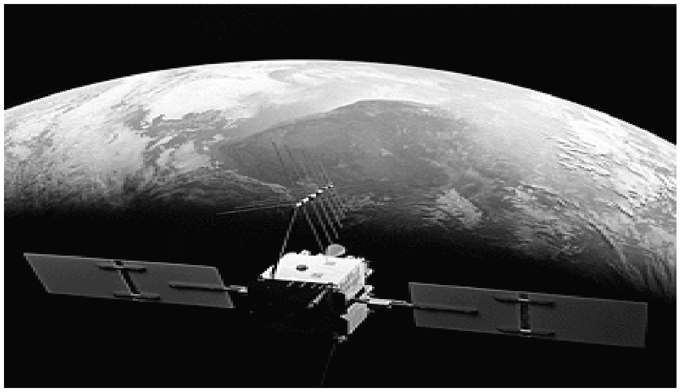
KEEPING UP WITH GPS TECHNOLOGY



Evolution in mapping and surveying technology has outpaced supporting mechanisms that enable engineering design and construction, spatial inventory and management of infrastructure, navigation and other forms of "smart" transportation applications. At the center of this rapid evolution is the Global Positioning System (GPS).

Although much has been reported on the accuracy of GPS, the "smarts" of the system are dependent on the extent of user input that define how the satellite data is collected and applied. Simply put, the more effort put into the GPS process, the better the results will be. The goal of this paper is to describe enabling GPS support efforts currently underway.

Challenges of GPS Implementation

The foremost challenge to entities implementing robotic systems, such as GPS-related technology, is insuring compatible, consistent, and reliable data flow. As with any automated robotic application, programming and controls are essential for success. Some factors that present challenges are:

- Advancements in GPS
- Advancements in GPS-influenced technology
- Increased GPS user applications
- Compatibility issues related to datum, adjustments, and geodetic models
- Space oriented system calibration to a national and/or local datum

Government Response to Evolving GPS Technology

Government entities, from local to federal levels, are implementing measures to address technical advancements in GPS-related technologies and applications. In the interest of increasing efficiency by making GPS-related technologies more readily available, while reducing liabilities by insuring compatibility, government is responding the following manner:

National GPS Constantly Operating References Stations (CORS)

The National CORS system comprises of a network of hundreds of GPS base stations whose data are made publicly available for various post-processing applications. In particular, CORS data is utilized to calculate GPS-derived positions with horizontal and vertical accuracies of less than a few centimeters. The National CORS system benefits from a multi-purpose cooperative endeavor involving government, academic, commercial, and private organizations.

National Science Foundation Studies Involve GPS/CORS

The *Pacific Northwest Geodetic Array (PANGA) Geodesy Laboratory*, located at Central Washington University, performs daily analysis of a regional network of more than 110 global sites (30 GPS stations in the Pacific Northwest) for crustal deformation, plate motion, volcano monitoring, and coastal hazards studies. The laboratory's primary scientific role is to support high precision geodetic measurements using the Global Positioning System (GPS) satellites, particularly for the study of earthquake hazards and sea-level processes.

The *Plate Boundary Observatory (PBO)*, a component of *EarthScope*, is a geodetic observatory designed to study the three-dimensional strain field resulting from deformation across the active boundary zone between the Pacific and North American plates in the western United States. The 10-year project, which is slated to begin in 2004, will consist of an array of nearly 900 Global Positioning System (GPS) receivers throughout California, Oregon and Washington.

National Height Modernization Program

The Height Modernization Program is a National Geodetic Survey (NGS) to enhance the vertical component of the nations geodetic reference network, called the National Spatial Reference System. Congressional appropriations, managed by the NGS, are earmarked to utilize GPS as a utility for the modernization of height applications such as air and marine navigational safety, precision agriculture and natural resources management, high accuracy flood plain mapping and real-time monitoring of gravity and aquifer-based water systems. Real-time applications also include topographical and environmental mapping, as well as robotic controlled construction and emergency equipment.

Spatial Reference Council of Washington

The Spatial Reference Council of Washington (SRCW) is being formed as an official organization to cooperate with the NGS to ensure that a high-accuracy horizontal and vertical reference network, based on GPS and related technologies and terrestrial techniques, is maintained in Washington State. The SRCW membership consists of local, state, and federal government entities. The primary purpose of the SRCW is to develop and implement strategies to utilize a statewide network of CORS, Real-Time CORS, and National Height Modernization Program.

Working under the direction of the National Geodetic Survey (NGS) and the Washington NGS Advisor, the Spatial Reference Center of Washington (SRCW) will hire staff to administer the program, perform studies, prepare and administer contracts, process data, and submit reports. Private consultants hired through a qualifications-based process will perform leveling contracts. Outreach to many other agencies and professions will be instrumental in accomplishing our goals. Training staff and consultants will help maintain quality data, system integrity, and maximize public benefit. SRCW activities will be monitored and directed by the Spatial Reference Council acting as the board of directors of the non-profit organization. The SRCW will work with the Washington State Dept. of Natural Resources (DNR) through a Cooperative Agreement, approved by the Washington State Office of Financial Management and provide grant funds as needed. The Spatial Reference Council has membership from a broad base of interested parties across the state, including the Dept. of Natural Resources, Dept. of Transportation, Pierce County, Snohomish County, and the cities of Seattle and Renton. Membership in the Council also includes the Land Surveyor's Association of Washington, Geographic Information Council, and Washington Council of County Surveyors. Two CORS stations, in Spokane and Snoqualmie, are to be installed and leveling performed to establish their elevations as first accomplishments of the new organization.

Puget Reference Station Network

The Puget Reference Station Network (PRSN) is a cooperative of real-time GPS networks offering survey data and real-time GPS correction services for the Puget Sound Region of Washington State. GPS data files from a network of continuously operating reference stations (CORS) are available to download to all, with real-time services available through partnerships, memberships, and subscriptions. The PRSN website (prsn.org) provides a rich content of services, support for users, system status and monitoring reports, solutions and tips from the community of users, and an open forum for users and other parties interested in real-time GPS. The PRSN is poised to go statewide in the near future.

The Puget Sound Reference Network (PRSN) is a multi-entity organization formed to facilitate the implementation of a Real-Time Kinematic (RTK) GPS utility. PRSN goals include reduction of RTK/GPS costs, while providing the benefits of a common regional reference framework. It is also the goal to avoid additional cost by combining the efforts of public entities currently operating GPS base stations or those proposing to do so.

GPS Satellite Tracking Stations

An important element in meeting across-the-board needs of academic/scientific; engineering/surveying/mapping, asset management, navigation and other users are the earth-based satellite tracking stations. Commonly referred to as "Constantly Operating Reference Stations (CORS)", these satellite tracking stations collect satellite signal data and send it to a processing center, via the Internet. These data are processed, analyzed, and archived for a multitude of uses.

An extraordinary degree of precision is gaining by utilizing highly stable mounting systems and data monitored over a long period of time. Because the need for precise data is required, criteria for selecting the type of platform for mounting a satellite-tracking antenna and its location/surroundings are important. Desired location criteria is as follows:

- Strategic location of network need
- Sub-surface stability dictates type of antenna mount platform
- Type of GPS receiver and antenna also dictates the degree of precision of data collected

- Obstructions to the GPS signal, such as trees or structures
- Multipath of reflective surfaces cause deflection of signal
- Radio signal interference cause GPS signal wavelength cycle slips
- Site security free of theft and vandalism
- Lease-free agreement with property holder
- Electrical power accessibility
- Communications accessibility (preferably Internet)

Once the antenna mount platform is installed, a GPS receiver is mounted in a nearby-weatherized lock box and wired for communications and power, including auxiliary battery. An underground coaxial cable delivers satellite data from the antenna to the receiver. The base station is then ready to deliver continuous data twenty-four hours a day for years to come.

Virtual Reference Station (VRS) for Improved Efficiency

A GPS receiver, operating in an independent manner, is only capable of 1-5 meter accuracy. Because GPS is a timing-based satellite-to-ground ranging utility, errors occur if the signal increases or decreases in speed during its 11,000-mile path through space. Some of the timing errors occur naturally, others are deliberately influenced for national security reasons. Timing errors have the effect of "offsetting" a true position. Various methods are implemented to try to eliminate these errors, but all center on the need for a second reference receiver stationed on a point with a known datum coordinate. The GPS rover unit, on the point to be surveyed, uses the "offset" information provided by the reference receiver to apply a "differential correction", thereby increasing accuracy.

Virtual Reference Station (VRS) is a communication tool designed to increase accuracy of GPS data. VRS provides real-time high accuracy location information via differential GPS and a cellular network. A network of multi-jurisdictional constant operating fixed GPS base stations send signal data, via Internet, to a central processing center to be analyzed and computed. The processing center then relays differential correction data to the user, via cellular communications. Users in the field with a single survey-grade GPS receiver have reliable real-time centimeter accuracy locating capabilities.

VRS Spatial Reference Center As A Utility

The cooperative will deliver real-time corrections utilizing Trimble VRS software. Users connect to cell phone w/modem, dial-in and receive corrections in reference to the nearest 3-4 base stations. Participating base station providers have direct access; others will be charged a fee (over their per-minute cell charges) to defer costs for establishing and maintaining the system. An Interlocal Master Agreement has been formed between WSDOT and Seattle Public Utilities enabling participation in VRS, while individual Task Agreements detail the level of participation.

VRS System Monitoring and Analysis

The data collected from each site is processed in a manner that analyzes GPS signal characteristics, as well as monitors overall network health. Network quality control monitoring for consistency and disclosure of events indicating antenna displacement or instability.

Signal analysis consists of data processing procedures designed to model space weather (ionospheric and atmospheric conditions). GPS technology derives its positioning abilities by calculating the range from the satellite to the ground, based on the amount of time the structured signal takes to travel through eleven thousand miles of space. Because ionospheric and atmospheric conditions vary, the signal will experience speeding, slowing, or deflection from its true path and elapsed time.

Models have been created to lessen the effects of these influences by utilizing two GPS signal frequencies. Each frequency has a different signal phase wavelength. The characteristics of each differing wavelength phase is modeled, based on its eleven thousand mile journey, and used by the GPS data processing for increased accuracy.

Greater distances between two GPS receivers result in greater differences in space weather conditions. Example: A two-kilometer GPS baseline measurement is likely to be affected far less than a 20-kilometer or 200 kilometer baseline. Emphasis on ionospheric on ionospheric and atmospheric modeling increases as measurement distances increase. Ionospheric and atmospheric modeling also increases in importance as Real Time Kinematic techniques rely on very short observation times of as little as 30 seconds rather than hours, as with static GPS techniques.

VRS System Improves RTK Results

The VRS system network combines the modeling information gathered from each site and applies an improved solution to the user/rover working within the boundaries of the VRS domain. Also, accuracy is increased by rover/processing center communications, based on the initial known position of the rover unit. A form of “coordinate seeding” is used at the rover site during its positioning process thereby reducing the effects of baseline length ppm anomalies.

Geographic Services Involvement In Multi-jurisdictional Action

The WSDOT Geographic Services Survey Section has been heavily involved with coordination and implementation of CORS/VRS since 2002 and is an executive member of Washington Spatial Reference Council. This council mirrors the activities of several other states, including California, to establish federal funding necessary to harness the utility of emerging Global Positioning System and communication technologies. As other states have done, this group directs efforts in obtaining federal funds for a central processing center, based the Department of Natural Resources in Olympia. The initial driving group behind the emerging technology has been the “Puget Sound Reference Utility”, formed by the City of Renton and Seattle, King, Pierce, Snohomish Counties, as well as Kitsap Public Utility.

Resources between multi-jurisdictional entities, throughout Washington State, are being coordinated to promote rapid development of Virtual Reference Stations (VRS) and secure Federal funding. Immediate efforts to employ VRS involve current Congressional approval of grants related to UNAVCO Plate Boundary Observatories, NGS Height Modernization Program, US Homeland Security and USDOT/FHWA Intelligent

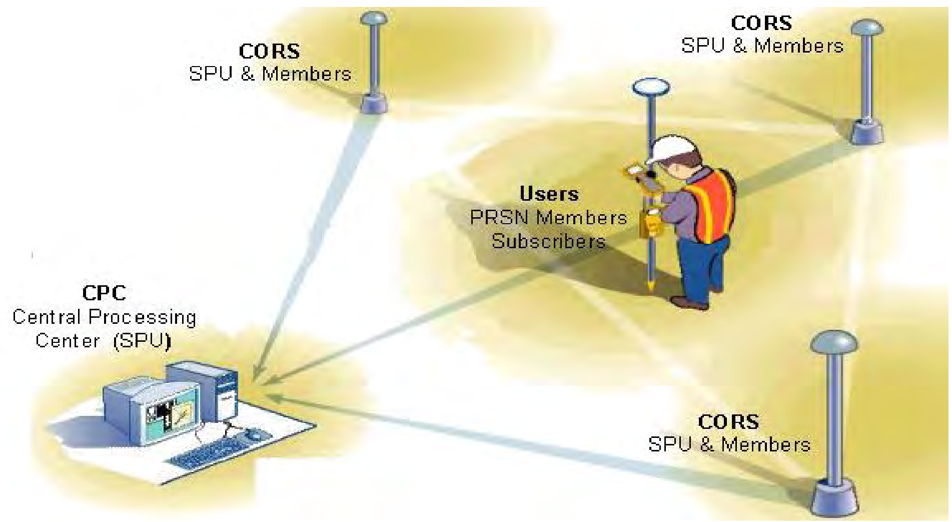
Transportation Systems. The Spatial Reference Council of Washington (SRCW) has been formed to direct development efforts. The initial council membership included representatives from:

- Central Washington University
- City of Renton
- City of Seattle, Seattle Public Utilities
- Land Surveyor's Association of Washington
- National Geodetic Survey
- Pierce County
- Snohomish County
- Washington Dept. of Natural Resources
- Washington Dept. of Transportation

The Spatial Reference Council of Washington considers WSDOT credibility and participation essential for success. Congress requires the NGS Advisor Program and WSDOT involvement for program qualification. Geographic Services has paid the $2000 initiation fee, representing WSDOT, and actively participates as one of three permanent executive Council roles.

Recently, Geographic Services created an Interlocal Master Agreement (GCA4314) with Seattle Public Utilities that enables WSDOT participation in the PRSN and made provisions for individual Regions, within WSDOT, to purchase VRS licenses by means of Task Addendums. This agreement methodology allows the greatest flexibility between participants.

Conceptual Model of the PRSN (VRS Network)
The PRSN is comprised of a network of regional CORS (Continuously Operating Reference Stations connected via the Internet to a Central Processing Center (hosted by SPU). These CORS are essentially a high-end GPS receiver with a geodetic-grade antenna on a very stable mount. The CORS dual-frequency receivers can be from any number of manufacturers; there are already Trimble, Geotracer, and Leica receivers, the choice of each CORS host. These CORS are at physically secure locations with reliable sources of power and Internet communications. These stations are typically located at 20-50km intervals but can maintain effectiveness even if spaced up to 70km apart (or more as has been tested in Europe).



These stations transmit a stream of GPS observations (collected from up to 10 satellites each) simultaneously to the CPC. Users of the services may utilize static GPS data files from the CPC via Internet or enhanced GPS data corrections in real-time.
Central Processing Center (CPC)
The CPC is a collection of physical servers and software that provides static GPS files, real-time corrections, network monitoring, and administrative functions. The components are standard SPU servers, and the Trimble © GPSNet/RTKnet suite of software running on standard Windows operating systems.
Static Files. The CPC also generates the static GPS files and posts these to the PRSN web server, transmits specific data to scientific and academic research concerns via FTP, processes requests for custom time-period & rate static files, and can generate a 'Virtual' static file which also includes atmospheric and orbital modeling. The user may download static GPS data files for 'post-processing' along with their own field observation files to derived accurate locations.
Monitoring. The CPC collects the data streams from the CORS, monitors the stability, quality, and availability of the CORS and their resultant data elements. The user may also view all network monitoring files and reports via the web interface. This option is important, as the user must review network status in determining fitness for use of any individual network elements or data products. The CPC monitors the positional integrity of the network to the millimeter, atmospheric, orbital, multi-path interference, and communications anomalies and transmits alerts to the administrator and users. All user transactions and account histories are recorded in databases
Real-Time Corrections. The CPC provides a central portal for users to access both traditional

Real-Time Kinematic GPS corrections from individual CORS, or the more enhanced Virtual reference Station (VRS) type of correction from multiple stations simultaneously. Access is via registered password protected accounts.

GPS Reference Station Install Costs and Considerations

Receivers

While most survey grade dual frequency GPS receivers will work as a base station, some have definite advantages over others. The Trimble NetRS GPS receiver represents one of the best values today as an unattended reference CORS station, especially if the Trimble VRS network is employed. In addition expanded connectivity and multiple data management functions, it will track the new L2c civilian signal. The $15,000 price includes networking VRS license, thereby reducing the initial cost to join the PRSN to a mere $1000.

The Leica GRX1200 Series GPS receiver is designed specifically for reference stations. They output RTK and DGPS data for transmission from the site by radio or phone, or for distribution from a control center by radio, phone or internet. The GRX1200 Series are true multi-tasking receivers as they can carry out many operations simultaneously, such as data files can be downloaded while continuing to track and log satellite information. Also, while streaming raw data, it can transmit RTK, DGPS, etc. Leica is developing a real-time network system utilizing “GPS Spider” software package that is designed to compete with Trimble “VRS”. When fully operational, the service will be commercially available through Leica dealers.

Antennas

Like the receiver, most geodetic dual frequency antennas with a ground plane will be sufficient for reference station operation. In the interest in reducing unwanted “noise”, a choke ring or choke ring style antenna should be considered. Choke ring antennas are a necessity for geodetic research applications dual frequency ground plane antennas cost about $2000 and choke ring antennas are about $8000.

Antenna Mounts

Antenna mounts can vary widely, but can be broken down into three main categories involving stability and cost. The most stable, but costly, is the deep drill geophysical mount used by PANGA and PBO. These labor and material expensive tripod-looking mounts are used extensively to monitor crustal movement. Deep drill monuments cost about $15,000 each. Their existence add value to any GPS/VRS system by providing a “backbone” of most stable stations from which to monitor others less stable. PANGA/PBO geophysical mounts cost about $15,000 each.

Medium-stability mounts, such as an H pile driven deeply into stable earth or steel pedestal embedded or bolted onto a large concrete mass delivers a good cross between stability and economy of construction. A well built medium stability pedestal mounts will cost about $2000 each.

The lowest stability, least expensive, and easiest mount to assemble is a building mount. The most stable building mount would be concrete structures or steel beam building with concrete or cement block walls. Building mounts offer the advantage of having accessible power and communications available. Building mounts typically cost less than $1000, but are subject to expansion and contraction as well as settling.

These three mounting categories should be considered similar to that of the survey hierarchy of 1st, 2nd, and 3rd Order standards and specifications. The most stable reference stations should provide the basis for controlling the secondary and then tertiary reference stations.

Communications and Power

The communication link from the CORS site to the central processing center can be addressed in many ways. The type of link used depends on the remoteness of the station and the availability of communication options in the local area of the CORS site. In order of desirability a T1, cable, or LAN link would be most efficient, followed by DSL, IDSN, then a dedicated telephone line, and a dial up as a last resort. In remote locations, telemetry is a commonly used option to send data to the nearest available communication link, but adds an expense of about $5000. In very remote areas, satellite data links are the only option.

In locations where available, standard 110-volt electrical service is run with communications by underground trenching. The receiver is in turn powered up by a converter and backed up with charged batteries, in case of external power failure. In remote locations, such as many of those operated by PANGA or PBO, solar power is a standard option. The receiver, antenna cable, communication and power links, modems, and back up batteries are contained in weatherized lock boxes, similar to those used by traffic signal operations. A complete dual frequency reference station set up, not including antenna mount, costs about $20,000.

GPS Rover Communications

Users can expect further development in the future regarding correction data communication links for rover operations. Until the advent of cellular modems for real-time GPS, only licensed radio frequencies of up to 25watts were available (except for under 2 watt short distance availability). In addition to the many options for standard cellular data packages offered by cellular venders, “extenders” and “boosters” can enhance cell phone range into areas not currently covered. Another option for remote operations is cell phone-to-radio repeater type apparatus for RTK. These technologies are being used elsewhere, as in Europe, but need to test here as latency problem could delay the real-time correction. Latency has an “offset” effect on the positions derived for the processing center correction data stream.

VRS Reference Station and Resource Mapping
Users involved with code receiver resource mapping now have several real-time options. In addition to using a beacon to receive RTCM radio corrections from dedicated CORS (meter to sub-meter accuracy), cellular-to-Internet modem allows VRS corrections for accuracies of about one foot! The Trimble GeoXT handheld, and other similar Leica products such as the SR20, GS20, and GIS DataPro, can greatly benefit from network modeling performed by VRS. A recent investigation by the NC Region involving the installation costs for two dual frequency GPS reference stations and two resource grade rover-receivers listed the following: *"2 GeoXT receivers and software package is $12,022.42, accessories for the GeoXT $2317.44 and the cost of 2 GPS base stations is $39,148.42 for grand total of $53,488.28. There will be additional charges such as TEF, cell phones purchase ($50.00/phone/rover) and cell service ($80.00/mo/phone), $1,000 one time fee to join PRSN per base, $600/month/base for maintenance fee to PRSN, and the cost of power and Internet to each base station. Installation cost will vary but I would average it to $5000 per base. There may be additional cost to run utilities to the base receiver form the source such as cables, conduits etc, etc.."*

CORS, Datum References, and Project Control

Datum Reference Choices
The following relationships become critical when VRS is employed on WSDOT projects:

Official Horizontal References

- NAD27, NAD83, NAD83/91, NAD83/98, NAD83/05 (CORS/HARN-referenced)
- CORS epochs, ITRF (time-tagged CORS-referenced)

Official Vertical References

- Bench marks with NGVD29 and/or NAVD88 elevations
- Ellipsoid Height improvements HARN observations and CORS
- Geoid Model improvements (Geoid96, Geoid99, 03)
- Refinements in local geoid model by further defining ortho elevation/geoid relationships

Current COR and VRS Compatibility Issues
National CORS deliver coordinate values that are not directly referenced to NAD83/91, therefore incompatible with HARN referenced points, such as those in the WSDOT Monument Database. In fact, because they measure the amount the earths crust is moving, CORS coordinates are published at regular intervals called "epochs". The coordinate is constantly changing and is said to have "velocity". Currently the PRSN has been physically tied to both existing HARN stations and CORS. The coordinates for the PRSN stations have been computed and adjusted to NAD83/91 and NAD83/98 NGS horizontal values by these survey ties. As a result, coordinates of monuments representing the WSDOT Monument Database fit very well. In the future, 2006 or 2007, the NGS will release a national readjustment of NAD83 and these same ties will begin to demonstrate incompatibility. In fact, WAC332-110-10 defines the legal definition of datum, when using state plane coordinates, as "NAD83, adjusted in 1991". Because of the new federal updated datum adjustment, the WAC will change. It is understood that,

while the new WAC language will allow, “any documented datum adjustment of NAD83”, migration to the latest (NAD83/05) will be necessary to achieve the best results from COR-derived data. Geographic Services will accommodate this issue by updating the entire Monument Database during the 05/07 biennium.

Future CORS/VRS Datum Compatibility Issues

As the PRSN expands from its existing Puget Sound boundaries to include Spokane, Clark, Yakima, and Wenatchee vicinities, or become statewide, it will need to provide a more universal method of addressing datum compatibility. Other similar VRS systems in the US and around the world utilize the World Geodetic System of 1984 (WGS84). This is the Cartesian system the GPS itself operates on (later converted to NAD83). A PRSN change to WGS84 will allow the user to transform or “calibrate” to any datum of choice. It also allows the user to maintain control of their own accuracy requirements, by performing the calibration necessary to meet the accuracy needs of any particular project. As with any survey, the greater the accuracy needs, the more effort needed to support those needs. As a general rule, resource mapping would need only the calibration on the CORS themselves, land surveying would need the calibration on the Primary Reference Network level, while mapping for design or construction layout will need calibration at the Project Geometric Framework level. These requirements are based on the need to further define geoid-to-ortho elevation relationships.

GPS Site Calibration Processes

The GPS site calibration process establishes the relationship between GPS-derived World Geodetic System of 1984 (WGS84) positions and a user-defined national or local datum. A local map grid can be assumed or a published grid, such as a UTM zone or a State Plane Coordinate System. The relationship between WGS84 and local coordinates is defined by a series of mathematical parameters. Mathematical transformations and conversions are applied in order to convert WGS84 positions to grid coordinates. GPS site calibration is an important process to successful integration of GPS techniques to survey measurements. The GPS calibration process comprises of:

A ***datum transformation*** to convert WGS84 coordinates to the latitude, longitude, and ellipsoid heights relative to a national ellipsoid (such as NAD83).

A ***map projection*** of the national datum ellipsoid latitude and longitude coordinates onto the local map grid as northing and easting coordinates (such as Washington State Plane Coordinate System).

A ***horizontal adjustment*** of the projected grid coordinates to best fit the local control values. This adjustment allows for any local variations in the projection system not treated by the datum transformation. These variations may include orientation and scale.

A ***geoidal undulation model*** (optional) to mathematically mimic the true geoidal surface.

A ***vertical adjustment*** to convert the heights referenced to the local ellipsoid to elevations above sea level or some vertical datum.

Calibration Issues Addressed- From the PSRN Website:

Posted: Thu Apr 28, 2005 10:49 am Post subject: Why do we need to calibrate?

Why do we need to calibrate when doing real-time GPS?

Datum references and accuracy demands are choices made by the users of the VRS network need to address network datum references. Then address the accuracy of the geoid model in your project region.

I want to stress that no GPS solution, from any source (or vendor) instantly creates a perfect geoid model.
The GPS satellites are referenced to the ellipsoid, a model that does have standard projections to published horizontal coordinate systems...so horizontal is not so much the issue. If you are using a project datum for horizontal, you can apply a factors (in the data collector) to yield direct results in project datum coords (this is a form of calibration or 'adjustment' as some like to call it).

The issue gets stickier in terms of vertical. To derive an orthometric elevation from GPS, one can apply a geoid model (derived from gravametric observations and published by NGS, or modified locally as Jerry Sims has done) and this gives the difference between the ellipsoid and, as best it can, the actual ground. Or, one can use the solid repeatability of the GPS observations as a sort of level, by checking in with local published vertical control and applying the difference that way rather than just the model on its own.

It depends what one is doing as to the method employed. Depending on the quality of the geoid model, one can test in a certain area and come up with a standard 'adjustment', or in some cases one is not needed at all.
For instance, in the central core of our network, and by total coincidence, our tests against published verts

means no adjustment for most work, but in the Kent Auburn area, the users there are developing adjustments
in the order of 3-7 hundreths for different regions.

Network users could decide to try to apply a sort of universal adjustment by doing level runs from nearby Harn
and applying those values to the stations rather than the pure ellipsoid values. In some cases this can nearly
eliminate the need for local adjustment (within reason). But what if, as is the case with vertical in some parts
of our network, that the vertical control is a hodge-podge of inconsistency. I have heard the statement for
over a decade of "gee, I checked in to this mon and this GPS is way off", yes but what was the source of the values
for that mon, how much may have things moved? GPS can have great fidelity to repeat observations and to the
ellipsoid, but measuring the earth is like trying to fit a squid for a tuxedo...alot of squirming...

Surveyors around here argue (sorry, discuss) at great lengths the merits of harn, cors, crustal movement,
subduction, iterations of adjustment and how everyone's control is suspect except thier own.
If HARN is the reference frame for your infrastructure and ultimately the coordinate base...then
it would probably be best to enter HARN derived values for stations in the sub-network and test against
the various vertical control resources for validity of the geoid model(s) avaialble.

Over time, wide networks tend to add purely space (GPS) based (i.e. WGS84) and work with the ellipsoid values, then
apply geoid models as are applicable and/or apply local callibration (adjustment). HARN based may work fine in tour region,
only time and testing will tell.

Height Modernization seeks to resolve the ambiguities and perfect the vertical reference framework for our state,
will this eliminate adjustment?...it surely will reduce a lot, but this is a moving earth, and GPS makes that very clear.
With conventional methods it was almost possible to hide from the 'moving earth', with GPS it is more obvious, but
quite manageable.

Hope this helps. It would be great if the SRCW could bring Larry Signani over there to talk to ya'll about this
subject. Larry is a national expert (and asset) on this subject, and he sees the issue of calibration as not spoiling the value
of real-time GPS.